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ROOF-BOLT RECOVERY IN THE MIDDLE WEST

BY L. W. KELLY

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by

L. W. Kelly[1]

CONTENTS

Page

Summary 1

Introduction 2

Acknowledgment 3

PART I

Bolt recovery by manual methods at four mines 3

Mine A 3

Mine B 5

Mine C 6

Mine D 8

PART II

History of the roof-bolt-recovery machine 10

Procedure 10

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Information Circular 7826

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CONTENTS (Con.)

Page

Bolt recovery by machine at eight mines 12

Mine E 12

Mine F 12

Mine G 13

Mine H 13

Mine I 14

Mine J 14

Mine K 15

Mine L 15

Discussion 16

Conclusion 17

ILLUSTRATIONS

Fig.

1. Roof-bolt recovery, mine A 4
2. Roof-bolt recovery, mine B 6
3. Roof-bolt recovery, mine C 7
4. Roof-bolt recovery, mine D 9
5. Roof-bolt-recovery machine 11

SUMMARY

The purpose of this paper is to describe several methods that have been employed in successfully recovering roof bolts in Indiana, Illinois, and western Kentucky coal mines, the States where successful roof-bolt recovery was started. As far as is known, the first bolts were recovered in a mine in western Kentucky in January or February 1951. In April 1951 a meeting was held at that mine to discuss the recovery of roof bolts. The meeting was attended by A. D. Sisk, former Chief, Kentucky Department of Mines and Minerals; and L. W. Kelly, Federal Bureau of Mines; and officials of the coal company. Inasmuch as roof bolting was in its infancy, the thinking regarding roof bolts at that time was on the problem of getting them in, not getting them out; consequently, the thought of recovering them was revolutionary. The subject was discussed at length from all angles, and it was finally agreed that, if certain safeguards were taken, no agency represented at the meeting would oppose the practice. That this decision was sound has been proved, as thousands of bolts have been recovered in the Middle West without a lost-time accident.

Recovering roof bolts is a simple operation; consequently, no complicated equipment had to be designed or built for this purpose. However, about 5 years ago, officials of the Traux-Traer Coal Co. conceived the idea and constructed a mechanical device for recovering bolts that has been very successful and has been copied widely in this area. This device will be discussed in detail in part II of this paper.

In mines where bolts are recovered manually three methods are used:

1. Support provided by permanent timbering.

2. Temporary support provided by roof jacks.

3. Support provided by a combination of roof jacks and permanent timbering.

Insofar as possible, this paper will show the cost of recovering the bolts and the value of the material that was recovered.

Roof bolting is expensive but essential in most mechanized mines. In all well-managed mines the axiom is that costs must be kept as low as is consistent with safety and good mining practice, and safety is the first consideration. If the mine operator is faced with the fact that the cost of supporting the roof is too high and he must either reduce the roof-bolting cost or revert to timbering, he has three possibilities:

1. The number of bolts in a given area may be reduced.

2. Shorter bolts may be used without changing the original pattern.

3. The bolts may be recovered from worked-out and abandoned places.

Obviously, a conscientious operator will not consider the first two methods without undergoing an experimental period as provided in the Code,[2] but in all probability he will consider the last. Roof-bolt recovery has been so successful in the Middle West that this practice will undoubtedly spread to all coal-producing areas of the United States where pillars are not extracted. This paper has been written with the hope that some practices and methods described herein may help operators who are thinking of recovering roof bolts.

INTRODUCTION

Roof bolting was introduced into coal mines in February 1947 at the No. 7 mine, Consolidated Coal Co., Staunton, Macoupin County, Ill. Since that time the development of roof bolting has been one of the most spectacular in the industry. Although more than 19 million bolts have been installed in the mines of Illinois, Indiana, and western Kentucky, many factors in their performance are still unknown. The only comparison available is to consider roof bolts in terms of timbers, the performance of which is known to any person familiar with mining. For instance, 1 bolt is considered to be the equivalent of 1 post, and a set of bolts is considered to be the equivalent of 1 crossbar. The recovery of timbers has been practiced for many years and is considered to be a normal mining operation; consequently, it follows logically that the recovery of roof bolts should also be considered a normal mining operation.

As a result of the first experiment in recovering bolts in a mine, referred to as mine A in this paper, an appreciable saving was made in the cost of material. This favorable news spread quickly throughout the mining areas in the Middle West, and now most of the coal mines in western Kentucky, Illinois, and Indiana are recovering bolts at a profit. In the 18 months following the first recovery of bolts, it was possible to get a reasonably accurate estimate of the number recovered, and the number was estimated conservatively to be 400,000. The recovery program was very successful from the beginning, and for the next few years the general practice in most coal mines in Illinois, Indiana, and western Kentucky was to recover roof bolts wherever safe to remove them. Wherever the program has been tried in the Middle West it has been successful, due entirely to the fact that in every mine where recovery was observed the officials have been extremely careful to safeguard the men recovering the bolts. In one mine a foreman was assigned to observe the two men who were doing this work. No hard-and-fast rules have been made as to the number of bolts that should be recovered in a shift. However, if any doubt exists about removing a bolt, the bolt in question is left in place.

The use of roof-bolt-recovery machines is increasing rapidly in the Middle West. The variance of results is great, due to several different factors, such as quality of the roof, propinquity of the bolts, size of the bolts, means of removing them to the room neck or shop, and diligence with which the men work. These factors are known to the operators and can be discounted or allowed for in a proposed roof-bolt-recovery program. The reason that the size of bolts is given as a factor is because 18-inch bolts can be handled more easily without fatigue than 5- or 6-foot bolts.

If approximately 400,000 roof bolts were recovered during the first 18 months in which recovery was tried, it is reasonable to assume that several million have been recovered to this time; however, no accurate count can be made. When it is considered that, according to available records, a lost-time accident has not occurred in the Middle West as the result of recovering roof bolts manually or mechanically, it is obvious that the methods used are safe and efficient and could serve, at least in part, as a guide to operators in other areas who are contemplating the recovery of roof bolts.

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[2] Federal Mine Safety Code - Part I, Underground Mines, art. III, sec. 1(b).

ACKNOWLEDGMENT

The writer wishes to thank all officials and workmen who gave their time and experience while the information contained in this paper was being collected.

PART I

BOLT RECOVERY BY MANUAL METHODS AT FOUR MINES

Mine A

Mine A is in Hopkins County, Ky. It is opened by a 210-foot shaft and an 825-foot slope to the Kentucky No. 11 coal bed, which averages 72 inches in thickness in this vicinity. The coal bed lies virtually flat and has a maximum cover of 250 feet. The room-and-pillar method of mining is followed, and the pillars are not extracted. The main entries are driven in sets of 4, 14 feet in width, on 60-foot centers and the room entries in sets of 3, 14 feet in width, on 60-foot centers. The rooms are driven 22 to 25 feet in width, on 45-foot centers. A total of 326 men is employed at the mine, and the average daily production is 6,000 tons of coal. All coal is loaded mechanically and broken down with permissible explosives after the faces have been undercut to a depth of 7 feet. The life of the mine is estimated to exceed 30 years.

The roof consists of various thicknesses of shale and limestone and supporting it is difficult. Its lack of uniformity requires the use of roof bolts ranging from 18 to 72 inches in length, depending on local conditions.

The mine was opened in 1949 and was one of the first in Kentucky to use roof bolts. The roof has been extremely bad in some places; as a result, the company officials have tried every conceivable combination of roof bolts, timber, and roof bolts and timber. The most hazardous roof conditions are caused by the frequent occurrence of slips, which appear to be more difficult to support in this mine than in other mines nearby in the same coal bed.

As a result of the many difficulties encountered in supporting the roof, the officials adopted the plan of using roof bolts only where they could be seated in limestone. In other places conventional timbering is used.

Because the distance from the top of the coal to the limestone varies so much, bolts ranging from 18 to 72 inches in length are used. The bolts are the headed, expansion-shell type, 3/4 inch in diameter, and are used with 6- by 6- by 3/8-inch steel plates. Some holes are drilled with rotary drills and some with stopers. Mechanical devices are used for tightening the bolts. Three bolts are used in a set, and the sets are installed longitudinally every 5 feet. So many bolts have been installed that it is impossible to give an exact number; a conservative estimate would be 950,000.

Two men recover the bolts; when they enter a room they first examine the roof carefully from the room neck to the face to determine the condition of the roof and how many and which roof bolts can be recovered. There is no inflexible rule as to the number that must be recovered, and the judgment of these two men determines which ones can be removed. They have been instructed to recover only those that they think can be removed without injury to themselves. Their first operation is to set 2 No. 9 screw jacks under the set of bolts nearest to the face and 2 more under the next outby set, as shown in figure 1. A 15-inch crescent wrench is then used to loosen the bolthead. The reason that such a short wrench is used is because the mine officials think that if a bolt is so tight that it cannot be loosened with a 15-inch wrench, a load may be resting on it, and to remove that particular one would not be safe. When about six turns of the bolt have been made, it is struck sharply with a hammer to drive the expansion plug upward and free the shell. The bolt is then unscrewed from the nut and recovered and a hook is inserted into the hole and the shell withdrawn. About 90 percent of the plugs and shells of the bolts recovered are withdrawn. When the first set of bolts is recovered, the two jacks are moved back to the third set from the face, and the same procedure is repeated until all bolts that it is possible to recover from the room have been recovered. When a jack is being removed, the practice is to loosen it a little and then listen for roof noises. If nothing is heard, the jack is removed.

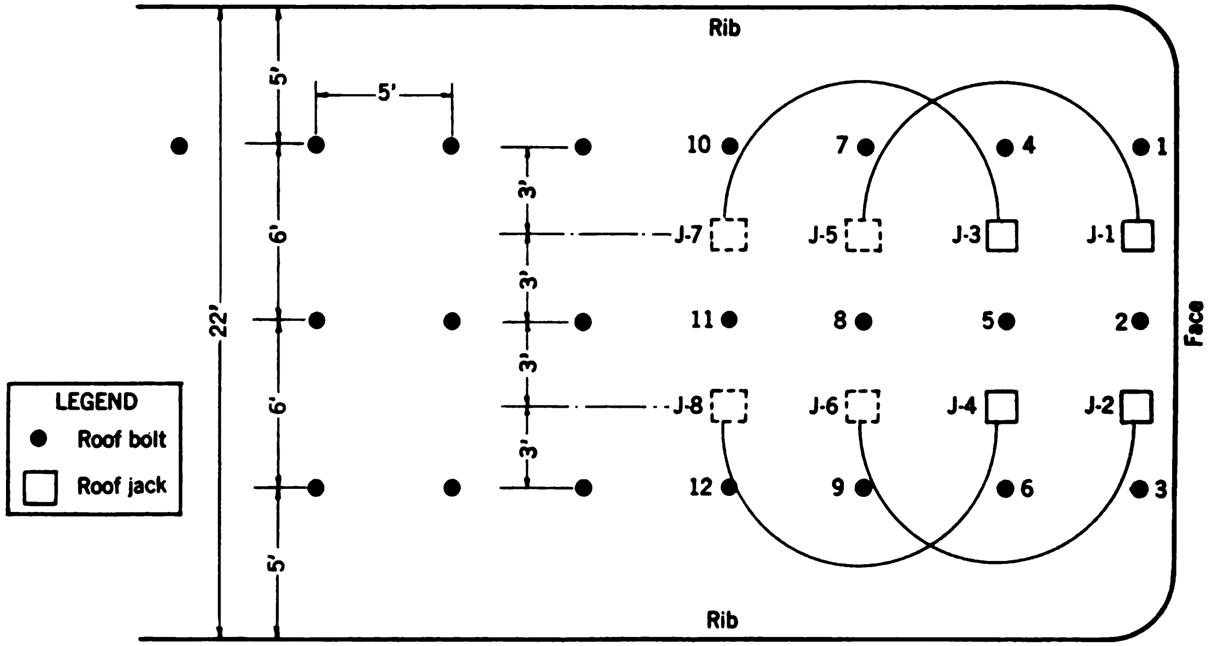

Figure 1. - Roof-bolt recovery, Mine A.

The men who do this work and have been doing it since roof-bolt recovery was begun in 1951 are capable and efficient workmen. It has been estimated that they have recovered approximately 350,000 bolts. Their precautions are reflected in the fact that only about 60 percent of the bolts are recovered.

An idea of the amount of money that was saved by recovering roof bolts in this mine can be obtained from the following:

Two men recovered approximately 290 bolts, plates, shells, and blocks in 1 shift.

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The cost of the material recovered is given below:

1	30- by 3/4-inch steel bolt[1]	$0.35
1	4- by 4- by 1/4-inch steel plate	.11
1	expansion shell and plug	.22
1	2- by 8- by 18-inch wooden block	.10
	Total	.78

[1] Bolts ranging from 18 to 72 inches in length are used, but a 30-inch bolt was used as the average length for this computation.

Thus, if 2 men at $20.04 each a shift recover 290 bolts and 260 expansion shells and plugs in 1 shift, a saving of $179.52 is indicated for 1 day after the wages of the 2 men are deducted.

Mine B

Mine B is in northern Illinois. It is opened by two 218-foot shafts to an uncorrelated coal bed, which averages 84 inches in thickness. The coal bed lies virtually flat and has a maximum cover of 230 feet. The room-and-pillar method of mining is followed, and the pillars are not extracted. The main entries are driven in sets of 5 and 6, cross entries in sets of 3 and 6, and room entries in pairs. All entries are driven 14 feet in width on 50-foot centers. The rooms are driven 20 feet in width on 50-foot centers. A total of 60 men is employed; of this number, 43 work in the mine. The average daily production is 1,200 tons of coal, which is loaded mechanically and broken down with Airdox after the faces have been undercut to a depth of 8 feet. The life of the mine is indefinite.

The immediate roof consists of 23 inches of hard, laminated (2-inch) gray shale, and above this occur successively 36 inches of hard blue shale and more than 72 inches of hard, laminated (4-inch) blue shale. Very few slips, faults, horsebacks, or rolls occur. Before roof bolting was adopted, the roof was supported by means of steel and wooden crossbars, set on 5-foot centers.

In September 1950 an experiment with roof bolts was made and was successful. Since that time their use has been expanded to the extent that approximately 225,000 bolts have been installed.

The bolts that are being used are 3/4-inch steel, 5 feet in length, equipped with expansion shells. Holes are drilled, and the bolts are seated by means of a shop-constructed drilling machine, which consist of two Dooley No. 474 electric drills mounted on a rubber-tired carriage. In the entries 2 bolts spaced 5 feet apart are used in sets spaced 4 feet apart. In the rooms 3 bolts spaced 5 feet apart are used in sets spaced 4 feet apart.

One man recovers the bolts. The first step is to deliver enough posts to the room neck to set 2 rows of posts up the center every 4 feet from the room neck to the face (See fig. 2.) The foreman then examines the place for any dangerous or loose roof rock and to determine whether or not it is safe to recover the bolts. The man who is to recover the bolts is instructed by the foreman to keep himself safe at all times, and, if the least doubt is in his mind about removing any bolt, he is to leave it. The first thing a workman does is to set 10 double rows of posts from the face outby, as shown in figure 2. Beginning at the face, he recovers the bolts until he reaches the eighth row of posts, where he sets 10 more rows and continues recovering bolts and setting posts until he arrives at the room neck. The posts are not recovered.

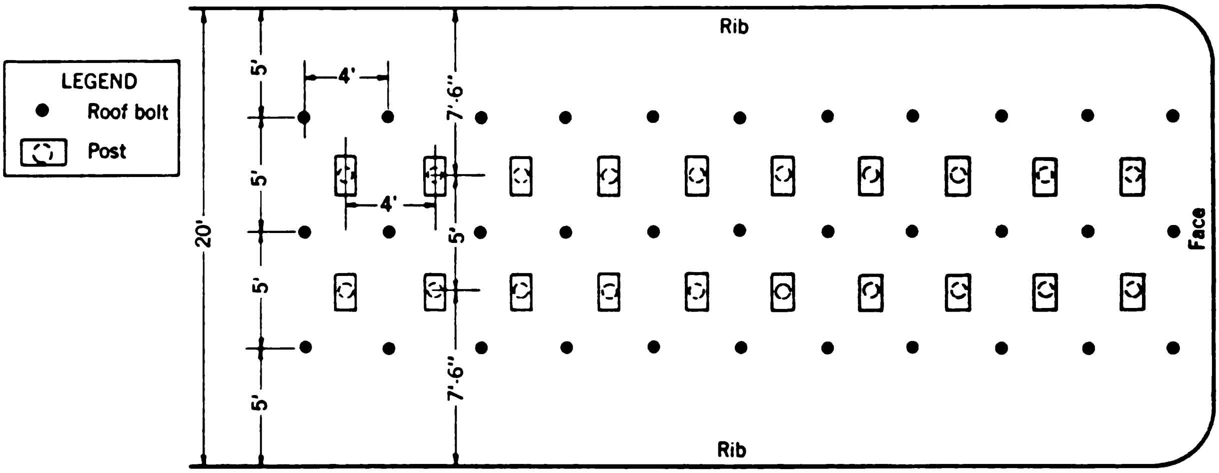

Figure 2. - Roof-bolt recovery, mine B.

The procedure in recovering the bolts is as follows: First, the roof bolt is unscrewed and removed, and an old bolt is screwed into the expansion plug and struck sharply with a hammer to loosen the plug and the shell; then the old bolt is removed, and the shell is recovered with an extracting hook. The reason an old bolt is used to loosen the shell is to keep from damaging the threads on the bolt that is to be re-used. The bolts that have been recovered are taken to an underground shop, where a mechanic brushes and oils the threads and replaces the palnuts. The bolts are used over and over and give good service until the threads wear out.

Since the recovery of bolts was begun in this mine, approximately 110,000 have been recovered. The roof in the mine is comparatively good, which, with adequate timbering, allows about 90-percent recovery of the bolts.

The cost of a complete bolt assembly is as follows:

1	60- by 3/4-inch steel bolt	$0.71
1	5- by 5- by 3/8-inch steel plate	.21
1	2- by 8- by 33-inch board	.22
1	expansion shell and plug	.27
	Total	1.41

One man recovers an average of 104 bolts in a day; consequently, the value of the material recovered by 1 man in 1 day is $146.64. From this, the cost of the posts ($24) and the wages of the man ($22.04), a total of $46.04, must be deducted, which leaves an indicated saving of $100.60 for 1 day.

Mine C

Mine C is in southern Illinois. It is opened by 2 slopes to the Illinois No. 6 coal bed, which averages 108 inches in thickness. The coal bed lies virtually flat and has a maximum cover of 160 feet. The room-and-pillar method of mining is followed, and the pillars are not extracted. The entries are driven 12 feet in width in sets of 6 on 34-foot centers. The rooms are driven 18 to 24 feet in width on 50-foot centers. A total of 384 men is employed, and the average daily production is 5,000 tons of coal. Some of the coal is loaded by a continuous miner, and the remainder by the conventional mechanical methods. The life of the mine is indefinite.

The immediate roof consists of 28 feet of soft, white, weak shale that disintegrates within 24 hours if it becomes wet. It is not laminated or stratified and has no lines of cleavage. When it fails, about 2 feet comes with the first fall, and the remainder follows quickly to a stratum of hard, black shale, 10 feet in thickness. This is considered to be the worst roof in the Middle West. The conventional method of timbering where roof bolts were not used consisted of installing 90-pound steel crossbars about 3 feet apart.

Roof bolting was begun in 1950, and after an experimental period it was decided to use 3/4-inch bolts ranging from 42 to 60 inches in length. The bolts were installed in pairs in entries and in sets of four, 3-1/2 feet apart in the rooms. The bolts are equipped with expansion shells and 6- by 6- by 3/8-inch steel plates. In addition to the steel plates, a 1-1/2- by 7- by 66-inch oak plank is used with each pair of bolts. A hole is drilled 6 inches from each end of the plank, and a bolt is inserted in each hole. Thus, 1 plank is used every 3-1/2 feet in the entries and 2 every 3-1/2 feet in the rooms. (See fig. 3.) Holes are drilled, and the bolts are seated by shop-constructed, mobile drilling machines.

Two men recover the bolts. Inasmuch as supporting this roof is exceedingly difficult, the officials do not attempt to tell the men which bolts to remove, and the men are not given any certain number to recover in one shift. When these men enter a place, they first examine the roof and determine in a general way the bolts they will try to recover. Removing the bolts is begun at the face, and in a normal place three 60-ton roof jacks are set, as shown in figure 3. The third jack is alternated from side to side behind the recovery men as work progresses. When the bolts are removed, the jacks are moved backward progressively. Sometimes only one bolt is

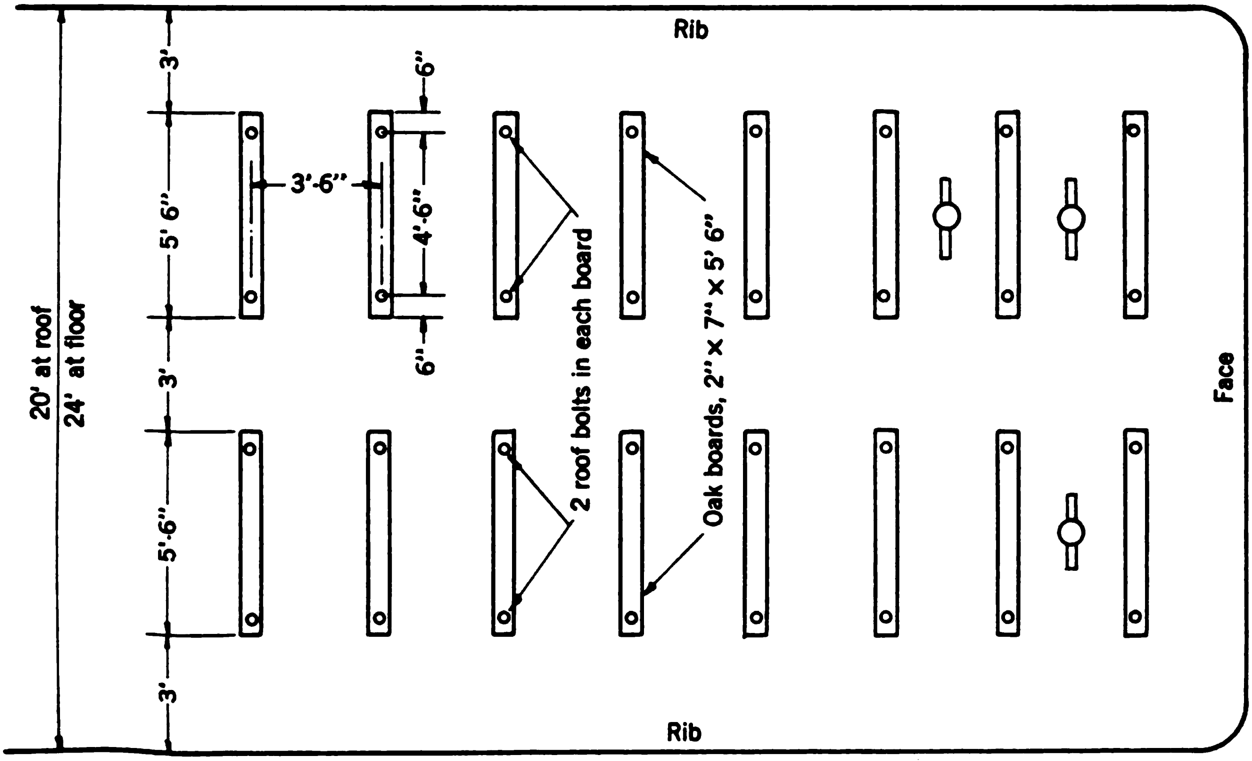

Figure 3. - Roof-bolt recovery, mine C.

removed from a board, and the board and the other bolt are left. Only about 30 percent of the bolts are recovered because of bad roof. Two men recover an average of 110 bolts in 1 day, and since this work was begun, approximately 210,000 bolts have been recovered. The policy of the company officials is to recover only the bolts where no possible hazard is evident.

An average recovery for 1 day by 2 men is as follows:

110	3/4- by 60-inch steel bolts at $0.62	$68.20
55	expansion shells at $0.24	13.20
110	6- by 6- by 3/8-inch steel plates at $0.22	24.20
31	1-1/2- by 7- by 66-inch boards at $0.40	12.40
	Total	118.00

From this must be deducted the wages of the 2 men, ($22.25 each) which leaves an indicated profit of $73.50 for 1 day.

Mine D

Mine D is in western Kentucky. It is opened by one 140-foot shaft and two 510-foot slopes to the Kentucky No. 11 coal bed, which averages 75 inches in thickness. The coal bed lies virtually flat and has a maximum cover of 300 feet. The room-and-pillar method of mining is followed, and the pillars are not extracted. The main entries are driven 8 abreast and the room entries in sets of 3. All entries are driven 14 feet in width on 50-foot centers. The rooms are driven 22 feet in width on 40-foot centers. A total of 310 men is employed, and the average daily production is 4,500 tons of coal, all loaded mechanically and broken down with Airdox after the faces have been undercut to a depth of 8 feet. The life of the mine is indefinite.

The immediate roof consists of approximately 13 inches of hard black shale overlaid by about 72 inches of limestone. Roof bolts are the principal means of roof support.

The bolts, of 3/4-inch steel, range from 18 to 60 inches in length and are equipped with expansion shells; 6- by 6- by 3/8-inch inch steel plates are used with the bolts. In the entries 3 bolts are installed in a set every 4 feet, and in the rooms 4 are installed in a set every 4 feet. The first experimental roof-bolt installation, made in 1950, was successful. Since that time approximately 550,000 bolts have been installed.

Roof-bolt recovery was begun in 1952, and since that time more than 200,000 bolts are estimated to have been recovered. The method of recovery, shown in figure 4, is as follows: A row of posts is set in the center of the room from the room neck to the face, and 2 roof jacks are then set in each of the 2 inby sets of bolts. The bolts in the set nearest to the face are recovered, and the roof jacks are moved back to the third set. This procedure is followed progressively until recovery is completed. The posts are allowed to remain in the room. A blueprint of figure 4 is provided for all members of the supervisory force and the men who are to recover the bolts. The following rules appear on the print:

1. Immediately after a bolted place has been worked out, set a row of props as shown.

2. Set safety jacks as shown in rows A and B.

3. Recover bolts in row A.

4. Move jacks from row A to row C.

5. Recover bolts in row B.

6. Move jacks from row B to row D - repeat.

Note: At least four safety jacks are to be set when any bolts are to be recovered.

Two men are used in this work, and they recover an average of 240 bolts a day. The recovery procedure is provided in printed form and an attempt is made to recover all bolts with due regard, of course, to safety. Their work is expedited by the fact that the company has provided an electrically driven tractor and trailer with which to transport the recovered bolts to the room necks or shop. About 85 percent of the bolts are recovered. The shells are not recovered.

Different lengths of bolts are used at correspondingly different costs, but for the purpose of this paper an average length of 24 inches is used.

The cost of one roof-bolt assembly is considered to be as follows:

1	24- by 3/4-inch steel bolt	$0.33
1	6- by 6- by 3/8-inch steel plate	.17
1	2- by 8- by 66-inch board	.40
	Total	.90

Thus, if 2 men at $20.04 each a shift recover 240 bolt assemblies, a total saving of $175.92 is indicated for 1 day after their wages are deducted.

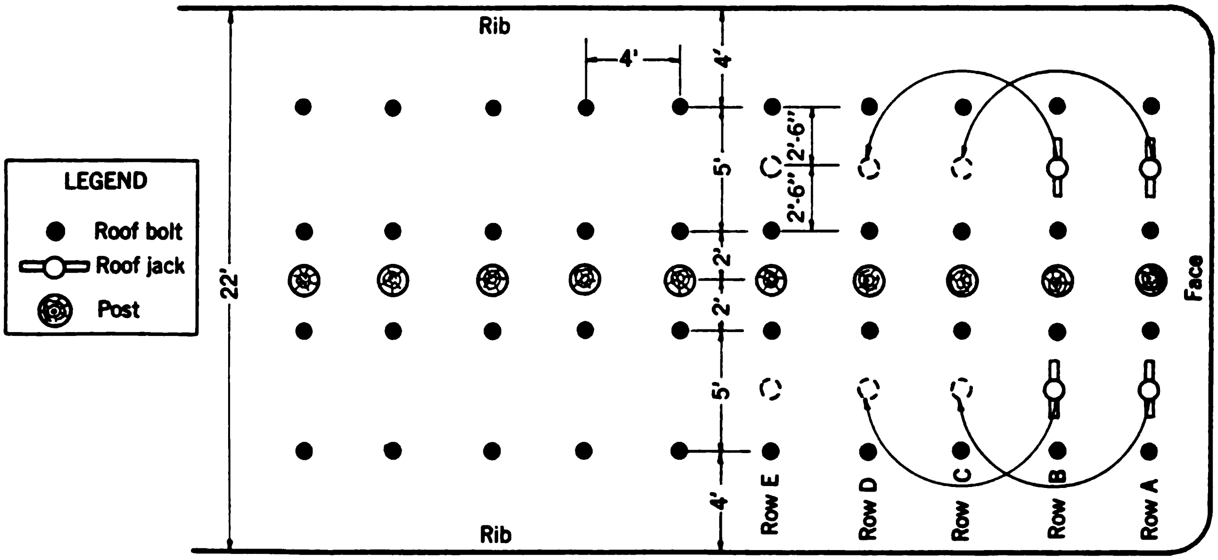

Figure 4. - Roof-bolt recovery, mine D.

PART II

HISTORY OF THE ROOF-BOLT-RECOVERY MACHINE

All the roof-bolt-recovery machines that are used in the Middle West are fundamentally the same, with a few local variations. The idea was conceived and the first machine constructed in 1952 by James Martin, general superintendent, Truax-Traer Coal Co. at the Victory mine, Terre Haute, Ind. Its use was successful, so another was constructed at the Burning Star mine, Truax-Traer Coal Co., Elkville, Ill. The first one made by another company was at the Bradbury mine, Midwest Utilities Coal Corp., Sparta, Ill. From these mines its use increased quickly throughout the Middle West.

The machine consists fundamentally of an electric drill locked or welded in reverse position, two rubber-tired wheels, and a light frame. (See fig. 5.)

The approximate cost to construct it was as follows:

1	Dooley 374 electric drill (obsolete)	$20
2	Model-A Ford wheels and axle	5
	Steel (plate and disk)	7
	2-inch pipe and welders' wages	18
	Total	50

The above figures were obtained from Mr. Martin and are authentic, although at some mines the cost has been as high as $400.

Procedure

The machine is operated by two men, but in many mines a third is employed on a shuttle car or other mobile truck to gather the bolts and transfer them to the room necks or the shop. The two men push the machine up to the last row of bolts; and, as the distance from the drill to the handle of the truck is 8 feet, the men are always protected by at least 1 set of bolts and in most instances 2 sets. The operator depresses the handle, which elevates the drill until the chuck engages the nut of the bolt. The weight of the handle is so balanced that the chuck will stay on the bolthead that is to be recovered. The operator has a thumb switch on the handle of the truck, which controls the drill. He turns it on and spins the bolt out of the expansion plug. He then raises the handle of the truck to a height that will let the bolt come out of the hole. The helper then reaches forward with a long hook and drags the bolt back under the protected roof. If a third man is on the shuttle car, he cleans the threads of the bolt with a wire brush and oils and loads them onto the shuttle car or truck. The shells are not recovered in any mine where a recovery machine is used.

When the bolts have been used several times, in many instances the threads become worn on the end. When this occurs, the helper saws off about 1 inch of the bolt and runs a die over the threads. The bolts are used until the heads are rounded from wear by the ordinary chuck, and then they must be discarded. However, it has been found that by using the universal joint (A-25429) from an 11-BU Joy loader as a chuck, this wear can be virtually eliminated. The universal joint is expensive but economical in the long run.

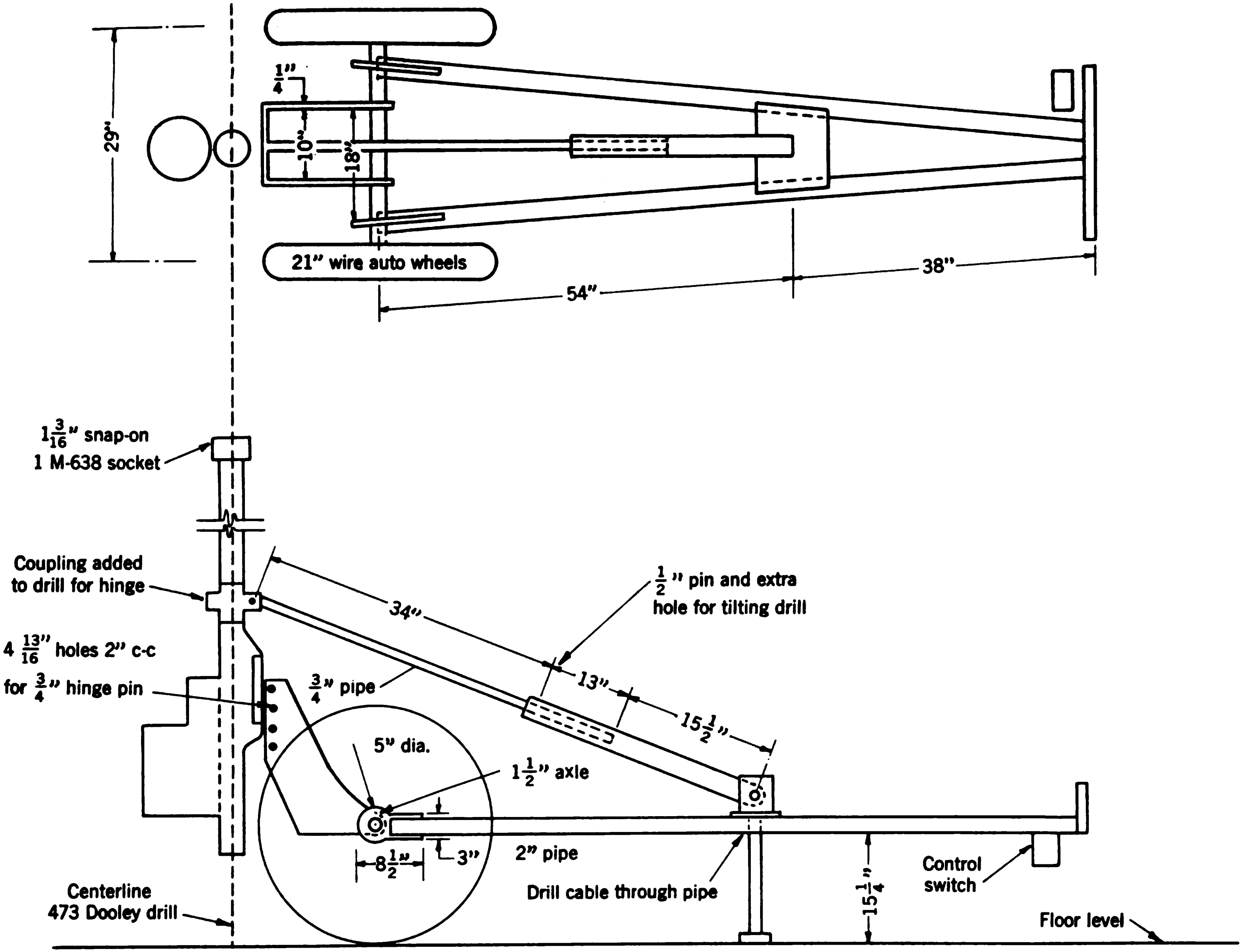

Figure 5. - Roof-bolt-recovery machine.

BOLT RECOVERY BY MACHINE AT EIGHT MINES

Results that are being obtained with the machine in eight mines are discussed in detail. Representative mines in Illinois, Indiana, and western Kentucky were visited, so that the results might not be considered local accomplishments. The mines are designated by letters of the alphabet.

Mine E

This mine is opened by 2 slopes into the Illinois No. 6 coal bed, which averages 7 feet in thickness. A total of 135 men is employed, and the average daily production is 3,500 tons of coal. The immediate roof consists of 3 feet of black shale overlain by limestone. Sometimes the shale disappears and is replaced by limestone as the immediate roof. All places are roof bolted with 3/4-inch steel bolts, 5 feet in length, which are installed 4 feet apart laterally and longitudinally and are kept to within 12 inches of the faces. Roof bolting was begun as the slopes were driven, and their use has been continued successfully.

About 90 percent of the roof bolts are recovered, and the roof-bolt-recovery machine is used exclusively for this work. Two men, equipped with a shuttle car, recover the bolts. They average 350 a day, and their maximum was 700 in 1 shift. No effort is made to recover the shells.

The value of one roof-bolt set is as follows:

1	60- by 3/4-inch bolt	$0.71
1	washer (used instead of a plate)	.0025
1	3- by 6- by 18-inch block	.12
	Total	.8325

The value of 350 sets is $291.37. From this must be subtracted the wages of the 2 men ($44.08), after which a saving of $247.29 is indicated for 1 day.

Mine F

This mine is opened by 2 shafts to a coal bed, which averages 84 inches in thickness. A total of 78 men is employed, and the average daily production is 1,650 tons of coal. The immediate roof consists of an average of 24 inches of laminated (2-inch) gray shale overlain by 36 inches of hard blue shale. All working places are bolted with 3/4- by 60-inch steel bolts installed 4 feet apart laterally and longitudinally. Roof bolts have been the major form of roof support since 1950.

About 72 percent of the roof bolts are recovered, and the roof-bolt-recovery machine is used exclusively for this work. Three men are used, 2 to recover the bolts and 1 to operate the shuttle car and clean and oil the threads of the bolts. They recover an average of 600 bolts in a day, and the maximum in 1 shift is 802. A long hook is used to pull the bolt recovered back under the supported roof. The recovery men have instructions to recover only the bolts that can be removed safely.

The value of one bolt assembly is as follows:

1	3/4- by 60-inch steel bolt	$0.71
1	5- by 5- by 3/8-inch steel plate	.21
1	2- by 8- by 33-inch block	.22
	Total	1.14

The value of 600 sets is $684. From this must be deducted the wages of the 3 men, and a saving of $617.88 is indicated for 1 day. This is outstanding.

Mine G

This mine is opened by 3 drifts in the Illinois No. 6 coal bed, which averages 90 inches in thickness. A total of 157 men is employed, and the average daily production is 3,100 tons of coal. The immediate roof consists of 6 inches of soft shale overlaid by 48 inches of hard shale. All working places are roof-bolted with 3/4- by 48-inch steel bolts, installed 4 feet apart laterally and longitudinally. Roof bolting was started in 1952 and is the major means of roof support. Approximately 80 percent of the bolts are recovered, and the roof-bolt-recovery machine is used exclusively for this work. Two men are employed on the recovery work and are provided with a shuttle car to transport the bolts recovered. As soon as a bolt is recovered, one of the men cleans it with a wire brush; if the threads need chasing he has a die for that purpose. He also oils the bolts and operates the shuttle car. The 2 men recover an average of 230 bolts a day. Expansion shells and plugs are not recovered. When the bolt is almost withdrawn from the hole, the recovery man bumps the machine forward sharply for 2 or 3 inches, and the bolt falls free and slides to the operator who is under the supported roof. All bolts are recovered at the discretion of the recovery men.

The value of one bolt assembly is as follows:

1	3/4-inch by 48-inch steel bolt	$0.52
1	6- by 6- by 3/8-inch steel plate	.17
1	3- by 10- by 20-inch block	.39
	Total	1.08

The value of 230 assemblies is $248.40. After the wages of the 2 men ($44.08) are deducted, a saving of $204.32 is indicated for 1 day.

Mine H

This mine is opened by 1 shaft and 2 slopes to the Kentucky No. 11 coal bed, which averages 75 inches in thickness. A total of 310 men is employed, and the average daily production is 4,500 tons of coal. The immediate roof consists of about 13 inches of hard black shale, overlaid by 6 feet of limestone. All working places are roof-bolted with 3/4-inch steel bolts, 18 inches in length, installed 4 feet apart laterally and longitudinally. Roof bolting was started in 1950, and roof-bolt recovery in 1952. About 60 percent of the bolts are recovered, and the roof-bolt-recovery machine is used exclusively for this purpose. Two men do the recovery work and are provided with a battery-driven car (not a shuttle car) for collecting and transporting the bolts. The 2 men recover an average of 550 bolts in 1 shift; the most that have been recovered in a shift is 756; however, 3 men were used that day. The recovery men use a long hook to pull the bolt extracted back under the supported roof where they are working. They have instructions to recover only the bolts that can be removed safely.

The value of a bolt assembly is as follows:

1	3/4- by 18-inch steel bolt	$0.21
1	4- by 4- by 1/4-inch steel plate	.10
1	3- by 8- by 33-inch board	.14
	Total	.45

The value of 550 assemblies is $247.50. After the wages of the two men are deducted ($40.08), a saving of $207.42 is indicated for 1 day.

Mine I

This mine is opened by a 300-foot slope and a 75-foot shaft into the Illinois No. 6 coal bed, which averages 84 inches in thickness. A total of 131 men is employed, and the average daily production is 3,200 tons of coal. The immediate roof consists of 2 to 7 feet of black shale overlaid by limestone. All the working places are roof-bolted with steel bolts that are 5 feet in length and 3/4 inch in diameter. They are installed 4 feet apart laterally and longitudinally. Roof bolting was begun in 1950, and roof-bolt recovery in 1952. About 85 percent of the bolts are recovered, and a roof-bolt-recovery machine is used exclusively for this purpose. Two men with a shuttle car are assigned to this work; they recover an average of 350 bolts in 1 day. The most that have ever been recovered in 1 shift is 805. The recovery men use a long hook to pull the bolts back under the supported roof, and no effort is made to recover the expansion shells and plugs. The men are instructed to recover only the bolts that they think can be moved safely.

The value of a bolt assembly is as follows:

1	60- by 3/4-inch bolt	$0.71
1	washer (used as a plate)	.0025
1	3- by 6- by 18-inch block	.11
	Total	.8225

The value of 350 assemblies is $287.87. After the wages of the two men are deducted ($44.08), a saving of $243.79 for 1 day is indicated.

Mine J

This mine is opened by a 950-foot slope and two 245-foot shafts to the Illinois No. 6 coal bed, which averages 90 inches in thickness and has a maximum cover of 300 feet. A total of 298 men is employed, and the average daily production is 4,800 tons of coal. All coal is loaded mechanically, some with conventional loading equipment and some by means of continuous miners. The pillars are extracted in the continuous-miner sections, but the bolts are not recovered. The immediate roof consists of approximately 20 inches of black shale overlaid by 15 feet of hard gray shale. All the working places are roof-bolted with steel bolts, 60 inches in length and 3/4 inch in diameter, installed 4 feet apart laterally and longitudinally. Roof bolting was begun in 1949, and roof-bolt recovery in 1954. All bolts are recovered currently by the recovery machine. No effort is made to recover the expansion shells or plugs. Two men do the recovery work, and in addition to the bolt-recovery machine are supplied with a shuttle car to transport the bolts. They recover an average of 310 bolts a day; no record is available on the maximum number recovered in 1 shift. A long hook is used to pull the bolts recovered back under the supported roof. The only bolts that are recovered are those where it is considered safe to remove them, as the men are instructed to maintain safety at all times.

The value of a bolt assembly is as follows:

1	60- by 3/4-inch steel bolt	$0.62
1	4- by 4- by 1/4-inch steel plate	.14
1	2- by 8- by 33-inch board	.33
	Total	1.09

The value of 310 assemblies is $337.90. After $44.08 is deducted for the labor of the 2 men, a saving of $293.82 is indicated for 1 day.

Mine K

This mine is opened by 1 slope and 1 shaft to the Kentucky No. 11 coal bed, which averages 72 inches in thickness and has a maximum cover of 260 feet. A total of 345 men is employed, and the average daily production is 6,600 tons of coal, all loaded mechanically. The roof varies greatly from area to area, but a representative section consists of 4 to 30 inches of soft shale overlain by 4 or 5 feet of limestone. As a rule, roof bolts are used only where they can be seated in limestone. Several different lengths of bolts are used; currently, the average length is 24 inches. They are 3/4 inch in diameter, equipped with expansion shells, and are installed 5 feet apart laterally and longitudinally. Roof bolting was begun in 1949 and roof-bolt recovery in 1951. All bolts are recovered by the recovery machine. Three men are employed on the crew, one of who drives the shuttle car and cleans and oils the bolts. They recover an average of 400 bolts in 1 shift, and the most that have ever been recovered is 500 in 1 shift. A long hook is used to pull the bolts extracted back under the supported roof. This recovery crew has had long experience in recovering bolts both manually and mechanically, and they recover only those whee it is considered safe to remove them.

The value of one bolt assembly is as follows:

1	24- by 3/4-inch steel bolt	$0.34
1	4- by 4- by 1/4-inch steel plate	.11
1	2- by 8- by 18-inch block	.10
	Total	.55

The value of 400 assemblies is $220. After the wages of the 3 men ($60.12) are deducted, a saving of $159.88 is indicated for 1 day.

Mine L

This mine is opened by two 585-foot shafts to the Indiana No. 3 coal bed, which averages 72 inches in thickness and has a maximum cover of 600 feet. A total of 388 men is employed, and the average daily production is 5,875 tons of coal, all loaded mechanically. The roof consists of approximately 72 inches of laminated gray shale, and supporting it is difficult. Roof bolts, 48 inches in length and 5/8 inch in diameter, are used in all places in the mine; they are installed 4 feet apart laterally and longitudinally. The bolts which have been recovered for only a comparatively short time, are removed by a recovery machine. Two men are employed for this work; they are not supplied with a shuttle car or any other type of mobile equipment for transporting the bolts. A hook is used to pull the bolts back under the supported roof. No effort is made to recover the expansion shells or plugs. The crew recovers an average of 300 bolts a day; no record exists of the maximum number that has been recovered in 1 shift.

The value of a bolt assembly is as follows:

1	48- by 5/8-inch steel bolt	$0.54
1	3- by 3- by 1/4-inch steel plate	.09
1	1- by 8- by 20-inch block	.10
	Total	.73

The value of 300 assemblies is $219. The wages of the 2 men are $44.08; consequently, a saving of $174.92 is indicated for 1 day.

DISCUSSION

The roof-bolt-recovery machine has been in use since 1952, and the number in use has increased steadily each year. No lost-time injuries have been connected with its use during these 5 years; consequently, in the absence of any evidence to the contrary it must be assumed that its operation is not one that could be considered particularly hazardous. In delving for possible hazards it could be thought that bolts might become weakened or elongated to such an extent that their ultimate tensile strength would be decreased to the point where the bolt would not be strong enough to support the load that it was designed for originally. In rebuttal, it could be said that any bolt that is subject to such stress, could not be recovered, as the conditions surrounding it would be too dangerous for its removal. Another possible hazard that could be considered is the use of bent bolts that have been straightened and are thus weakened; however, nothing in the recovery process will bend a bolt, so this possibility can be dismissed. In instances where a bolt has been used over and over to such an extent that the threads are becoming burred, this condition will be discovered by the man who cleans and oils the threads or when a new shell is being screwed onto the bolt. If this condition is found to exist, the practice is to discard the bolt or to cut off the burred portion and chase the threads with a die that is furnished for that purpose.

The areas from which roof bolts have been recovered are usually sealed; sometimes they are barricaded and marked with a DANGER - KEEP OUT sign. In some instances an area may cave quickly, and sometimes these areas are not barricaded or marked with a DANGER board.

Regardless of any precautions, the chance always exists that something may go wrong and an accident occur; consequently, the following suggestions and recommendations are offered. Some may seem to be elementary; nevertheless, all are founded on experience:

1. When roof-bolt recovery is begun, assign practical, capable, and well-trained men on the job.

2. Once the recovery crews are established, do not change them.

3. Use a long hook to pull the bolt extracted back under the supported roof.

4. Do not try to recover expansion plugs and shells.

5. Have each bolt that is recovered cleaned with a wire brush, oiled, and thoroughly inspected to determine damage or defect.

6. Damaged or defective bolts should be discarded.

7. If the heads of the bolts are being rounded, use the socket that has been described in this paper (p. 10).

8. Recover the bolts as quickly as possible after the place has been driven.

9. Do not recover bolts in a section near mining, as the noise incidental to mining operations may make it difficult for the recovery men to hear movements of the roof where they are working.

10. The recovery crew should consist of a minimum of two men.

11. If possible, recover the bolts during an odd shift or an idle day when everything is quiet and the recovery men can hear all noises distinctly.

12. Instruct the recovery men to use their own judgment as to the safety of recovering a bolt or group of bolts, and if the slightest doubt is in their minds to leave the bolts in place.

13. Barricade unsealed areas from which roof bolts have been recovered and mark them plainly with DANGER - KEEP OUT signs.

CONCLUSION

Roof-bolt recovery is now an established practice in Illinois, Indiana, and western Kentucky. The foregoing examples are the best that were observed, although all mines use some variation of a method described in this paper. The obvious reason for roof-bolt recovery is its favorable impact on the cost per ton of mining coal. In many instances this saving is the difference between using roof bolts and not using roof bolts, and, to carry this line of reasoning farther, many mines could not operate with modern mechanical equipment without using roof bolts. Consequently, the recovery of roof bolts is the factor that keeps many mines operating in the Middle West. The experience in using recovered bolts over a period of several years has been very good and there have been no failures of recovered bolts.

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